Diversity and abundance patterns, and revised checklist, of saturniid moths from Borneo (Lepidoptera: Saturniidae)

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Abstract: We investigate species diversity and faunal composition of Bornean saturniids in different habitats, using quantitative light-trapping data. With a sample size of 324 specimens (from 12 sites) it was not possible to find statistically significant effects of habitat disturbance, whereas faunal composition differed between altitude classes of sites. On a larger data set of 30 sites we tested the idea that patterns of local frequency within the large-bodied Bombycoidea can be understood in the context of their life histories. In particular, ecological correspondence was expected between (adult non-feeding) saturniids and some non-feeding sphingid groups, whereas opposing trends should occur in adult feeding sphingid groups. Data indicated that the specimen frequency of saturniids declined with increasing habitat disturbance, but effects were not statistically significant. An expected negative relationship was recovered for the relative specimen frequency of saturniids and some adult-feeding sphingid groups. However, no positive correlations were shown between the non-feeding groups. Furthermore, the (adult-feeding) sphingid tribe Ambulycini generally showed frequency patterns more similar to the non-feeding groups. Hence, data did not provide unequivocal support for the hypothesis stated above. As Appendix we provide an updated checklist for the 27 species of Saturniidae today known to occur on Borneo, accounting for taxonomic revisions and new records since the publication of an older standard reference.

Artenreichtum, Häufigkeitsmuster und aktualisierte Checkliste der Saturniidae von Borneo (Lepidoptera: Saturniidae)

Zusammenfassung: Wir untersuchten anhand quantitativer Lichtfänge den Artreichtum und die Artenzusammensetzung von Saturniiden in verschiedenen Habitaten auf Borneo. Bei einer Stichprobengröße von 324 Individuen (von 12 Sammelorten) konnten keine statistisch signifikanten Effekte der Habitatstörung nachgewiesen werden, wir fanden jedoch Unterschiede in der Fauna verschiedener Höhenzonen. An einem größeren Datensatz von 30 Sammelpunkten untersuchten wir, ob die lokalen Häufigkeitsmuster der großen Bombycoidea im Kontext ihrer Biologie verstanden werden können. Wir erwarteten ökologische Ähnlichkeiten zwischen Saturniiden und einigen Gruppen der Sphingidae, die als Adulttiere keine Nahrung aufnehmen, während reziproke Muster in denjenigen Sphingidengruppen, die als Adulttiere saugen, auftreten sollten. Die Daten zeigten, daß die relative Häufigkeit von Saturniiden mit zunehmender Störung der Habitate abnahm, dieser Effekt war jedoch statistisch nicht signifikant. Wir fanden, wie erwartet, negative Beziehungen zwischen den relativen Häufigkeiten von Saturniiden und einigen der adultsaugenden Sphingiden, aber wir fanden keine positive Beziehungen zwischen den verschiedenen nichtsaugenden Gruppen. Außerdem zeigte sich, daß die (adultsaugende) Sphingidentribus Ambulycini Häufigkeitsmuster zeigte, die eher denen der nichtsaugenden Gruppen ähnelten. Zusammenfassend ließen sich also keine eindeutigen Beweise für die oben beschriebene Hypothese finden. Als Anhang präsentieren wir eine aktualisierte Checkliste der 27 heute von Borneo bekannten Saturniidenarten, die die taxonomischen Revisionen und Neunachweise seit der Publikation eines älteren Standardwerks zusammenfaßt.

Introduction

Local biodiversity patterns of Lepidoptera under different habitat conditions, such as along gradients of altitude or human-inflicted habitat disturbance, have been intensively studied in Southeast Asia and particularly in northern Borneo (e.g. Holloway 1976, Holloway et al. 1992, Intachat et al. 1999, Willott 1999, Chey 2000, 2002, Hamer et al. 2003, Fiedler & Schulze 2004, Cleary & Genner 2006, Beck et al. 2002, 2006a, Beck & Chey 2007). Their investigation is not only interesting for academic understanding, but also provides information that is necessary for the conservation of invertebrate biodiversity, an issue of great importance in the wake of the current habitat destruction in SE-Asia (Sodhi et al. 2004). Lepidoptera have often been viewed as suitable "indicators" of arthropod biodiversity (e.g. Sutton & Collins 1991, Summerville et al. 2004; but see Nordén & Appelqvist 2001). For many taxa (e.g. Pyralidae, Geometridae, Arctiinae, fruit-feeding Nymphalidae) a decline of diversity with increasing habitat disturbance has been shown at local scales (Schulze 2000, Beck & Schulze 2000, Beck et al. 2002, Fiedler & Schulze 2004, Cleary & Genner 2006), whereas some taxonomic groups apparently show reversed trends or little reaction at all (e.g. Hill et al. 2003, Beck et al. 2006a).

Little is known of the diversity patterns of SE-Asian Saturniidae (a family of the bombycoid moths) despite their long-standing attractiveness to collectors, and resulting interest in their systematics, taxonomy and larval hostplants (e.g. Holloway et al. 2001). Reasons for a lack of quantitative ecological data are their relative rarity in light trapping samples in the Asian tropics, combined with their habit of generally flying rather late at night.

Janzen (1984) has pointed out in a classical paper on Costa Rican "big moths" that ecological and behavioural differences between different bombycoid taxa can be interpreted in the light of life history variations related to the presence (sphingids) or absence (saturniids) of adult feeding (as concluded from morphological features of the proboscis). Sphingidae were characterized

[1] 71st contribution to the knowledge of the Saturniidae.

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as being active, long-lived and not sexually dimorphic, with continuous egg-production and single-egg oviposition. Their larval host plants are often rich in nutrients, but require detoxification due to specific protective chemicals, such as alkaloids. Saturniidae, on the other hand, were typically short-lived, have a high degree of (morphological and behavioural) dimorphism, mass-oviposition, and larva feeding on host plants poor in nutrients, containing chemicals that impair effective digestion, such as phenolics. Links between such life-history parameters have recently also been investigated in other Lepidoptera groups (e.g. Jervis et al. 2006, 2007, Beck 2007).

In SE-Asia, saturniids are much less speciose than in the Neotropics (only one subfamily, Saturniinae, occurs), whereas the non-feeding sphingid tribe Smerinthini is abundant in Asia, but largely absent from the New World (Kitching & Cadiou 2000). Holloway (1987) suggested that Smerinthini (and other bombycoids, such as Lasiocampidae and Eupterotidae, which were not treated in this study) take over the "ecological role" of saturniids in the Asian tropics. Corroborating this idea, he pointed out similarities in larval host plant choice (on family level) within the corresponding groups in Costa Rica and Borneo, but clear differences between these groups within both regions (see also Beck et al. 2006b).

In a recent analysis of a large data set of sphingids in Borneo, Beck et al. (2006a; see also Schulze 2000) expanded the ecological dichotomy between sphingid subfamilies to habitat choice. Macroglossinae and Sphinginae apparently profit from forest disturbance, whereas Smerinthinae decline in relative abundance with increasing disturbance. Preferences for stable or disturbed habitat, respectively, were tentatively interpreted as consequences of adult feeding, such as variation in dispersal ability due to adult life-spans or flight ability (see also Beck & Kitching 2007, Beck 2007). Furthermore, distinctive differences between life history groups within the Sphingidae were also reported at a larger spatial scale (Beck et al. 2006c).

In this article basal information on the biodiversity and relative abundance of saturniid moths from different habitats on Borneo is provided. Furthermore, in a comparison to data on various sphingid groups, we investigate the idea that life history groups share similar frequency patterns under variable habitat conditions. As Appendix we provide a checklist of saturniids currently known from Borneo, applying nomenclature revised since Holloway (1987) and commenting on current issues of taxonomy of the taxa.

Methods

Study region and field methods

The northeast of Borneo is an only weakly seasonal, tropical region that was, until recently, almost entirely covered in rainforest (Marsh & Greer 1992). The last five decades, however, have seen massive landscape conversion due to industrial-scale logging and plantations. For many higher plant and animal taxa very high species richness was recorded, leading to the recognition of the region as a global "biodiversity hotspot" (e.g. Myers et al. 2000, Kreft & Jetz 2007). Contributing factors are probably the stability of the region during Pleistocene climate changes (Taylor et al. 1999) and the presence of high mountains, which provide isolated highland habitats containing many endemic taxa (Wong & Phillips 1996).

Light-trapping surveys were carried out across the Malaysian state of Sabah, as well as at two sites in Indonesia's East Kalimantan province, from 2001 to 2003 (see Appendix for site locations). A generator-driven, 125 Watt MV bulb or three combined 15 Watt blacklight tubes (at less accessible sites) were used as light source. Members of the large-bodied bombycoid families were hand-sampled from the light and surrounding vegetation. Each site was sampled for 3–9 nights in a row, generally sampling from dusk to dawn to ensure inclusion of taxa flying late in the night (see also Beck & Linsenmair 2006). Some sites were re-sampled after a minimum of six months. As generally little seasonal effects were observed (e.g. Beck & Linsenmair 2006 for sphingids), those data were pooled for the purposes of the present study.

Saturniids and sphingids arriving at light were identified in the field following Holloway (1987). However, while sphingids were collected or photographed in all difficult taxa for later determination by a specialist, specimens of the Saturniidae were not collected except if they were clearly distinct from specimens pictured and described in Holloway (1987; e.g. Nässig & Beck 2005). Instead, most specimens were marked with a waterproof pen on their wing (in order to avoid pseudoreplicates in following nights) and released at dawn.

Additionally to own sampling, published data on Sphingidae and Saturniidae from the Mt. Kinabalu region (Holloway 1976) were used. Furthermore, for analyses of relative abundances (see below) we also referred to data from an expedition to Gunung Mulu National Park in eastern Sarawak (six sites; Holloway 1984 & J. D. Holloway, pers. comm.). Analyses of sphingid data were presented in Beck et al. (2006a), where further details can be found. Only sites with at least eight saturniid specimens were used for analyses of diversity and faunal composition, whereas more sites were available for analyses of their relative abundances.

Taxonomy

Nomenclature and taxonomy of several saturniid taxa have been revised since the publication of Holloway's (1987) treatment. As only selected specimens were collected by the first author, not all specimens could later be determined with certainty according to current taxonomic standings. Furthermore, in a number of taxon-complexes species identities of Borneo specimens are generally not fully resolved. While this poses only minor problems for objectives of the analyses presented here,

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raw data should not be taken uncritically for other purposes (see Appendix for further details).

For the purposes of this study we differentiate between four "eco-taxonomical" groupings of the Sphingidae — the subfamilies Macroglossinae and Sphinginae as well as the tribe Ambulycini, which feed as adults, and the combined tribes Smerinthini and Sphingulini (the latter consisting of a single, uncommon species in Borneo), which have no functional proboscis. These groups do not, however, necessarily represent monophyletic clades. Sphingid phylogenetic relationships are currently being revised based on molecular data (I. J. Kitching, pers. comm.).

Analyses

Within-habitat diversity was measured by Fisher's α, which has been proven a suitable measure of diversity (independently of sampling effort, i.e. specimen numbers) in many critical studies (Southwood & Henderson 2000, and references therein).

The faunal similarity of sites was compared according to the *chord-transformed normalized expected shared species* (CNESS: Trueblood et al. 1994). This measure considers species' abundance and is robust to incomplete samples (unlike most other measures of beta-diversity), a prerequisite for the analysis of tropical invertebrate samples. An increase of its parameter *m* allows weighting for rare species in samples. CNESS-values with *m* = 8 were subject to a non-parametric randomization technique (Anosim; computed with Primer vers. 5) to test for statistical significance of relationships between community similarity and environmental categories. For this purpose, habitats were classified as lowland (200–400 m), mid-elevations (550–1200 m) and highlands (1500–2150 m) with respect to altitude, and as primary forest, secondary forest, or open farmland/ plantation with respect to habitat disturbance.

To compare abundance patterns of different life-history groups within the large-bodied bombycoids, prevalence of Saturniinae and four sphingid groups (see above) were calculated as their specimen numbers divided by the combined catch of these groups (covering the majority of "large" bombycoid specimens). Raw abundances from light-trapping cannot easily be compared between sites due to confounding effects of weather, moonlight and temperature (e.g. Yela & Holyoak 1997). Generalized Linear Models (GLMs; computed with Statistica vers. 6) were used for multivariate tests of disturbance-class and elevation effects on response variables such as diversity or relative frequency.

Results

Saturniid moths are a rarely encountered group in Bornean light-trapping samples. In 146 nights at 18 own sampling sites (1415 collecting hours), only 316 specimens, covering 17 of the 24 recorded species of Malaysian Borneo, were found (Appendix). At the same time > 5200 sphingids could be sampled, although this family is also not usually very abundant at artificial light sources. Together with published and unpublished samples (see above for sources), quantitative data from 30 sites in Borneo were available, comprising 347 saturniid specimens.

Diversity of saturniids

For the investigation of diversity and faunal similarity data from 12 sites, comprising 324 specimens of 18 (morpho-)species, were used (own sampling, see Appendix, and data from Holloway 1976: HQ, K, PS). Only one of these sites (Por8) was of the of "high disturbance" category. Fig. 1 displays diversity in relation to elevation and habitat disturbance. Although the fitted surface suggests high diversity in lowland primary forests, but low values at disturbed highland sites, GLM analysis did not yield significant effects of either variable ($R^2 = 0.10$, $F_{3,8} = 0.31$, $p = 0.817$; univariate tests: disturbance — $F_2 = 0.37$, $p = 0.703$, elevation — $F_1 = 0.415$, $p = 0.537$). However, while not statistically significant, diversity did decrease with increasing disturbance — from mean Fisher's $\alpha > 3$ in primary forests to $\alpha = 2.0$ at the open farmland site. A rank correlation did not indicate a relationship between elevation and Fisher's α (Spearman's $R = -0.23$, $p = 0.476$), whereas the number of specimens caught (and consequently the number of recorded species) significantly decreases with increasing elevation (specimens: $R = -0.580$, $p = 0.048$; species: $R = -0.576$, $p = 0.050$).

A noteworthy feature is the difference between the sites Dv1 and Dv1a, being located on a canopy tower in 40 m height (Dv1) and in the dense forest understorey beneath it (Dv1a). A randomization test (Solow 1993) reveals that the canopy sample is significantly more diverse than the understorey ($p_{1\text{-sided}} < 0.001$). Dv1a was the only site where saturniids made up the majority of the bombycoid catch.

Faunal similarities of saturniid assemblages

Anosim (5000 runs) revealed significant differences of the faunal composition of three altitude classes (Global $R = 0.267$, $p = 0.043$). In particular, there were significant differences between lowland and highland sites (pairwise comparison: $p = 0.016$) and a marginal trend for a difference between mid-elevations and the highland fauna ($p = 0.057$), whereas no differences could be found between lowland faunas and that of mid-elevations ($p = 0.696$). There were no distinct faunal differences between disturbance classes ($R = 0.037$, $p = 0.397$; all pairwise comparisons $p > 0.20$). Multivariate Anosim (2-way cross-design, not shown in detail) did not alter these conclusions.

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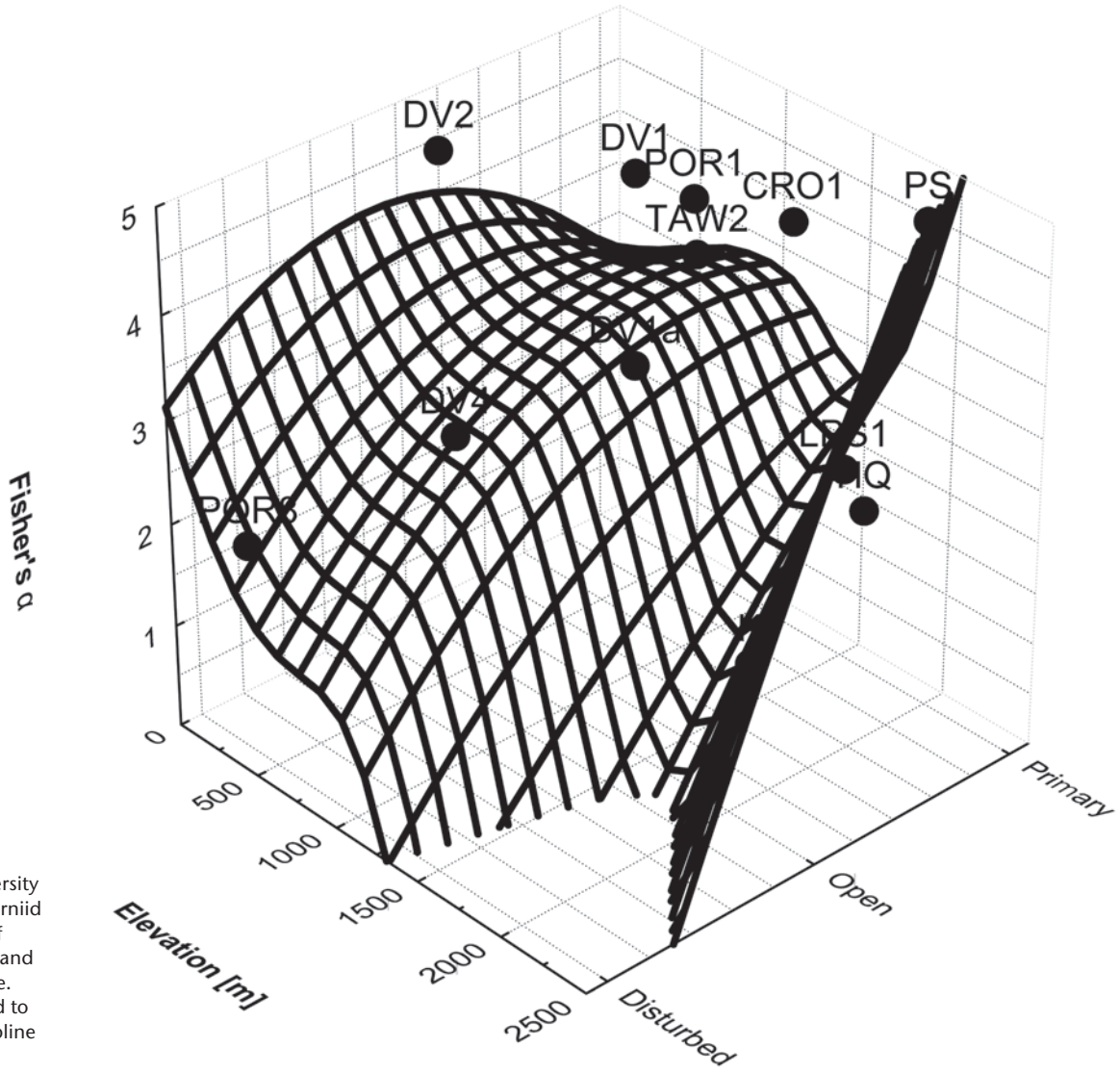

Fig. 1: Species diversity (Fisher's α) of saturniid moths at 12 sites of different elevation and habitat disturbance. A surface was fitted to data for display (spline regression).

Relative frequencies of adult feeding and non-feeding groups

Fig. 2 shows relative frequencies of five eco-taxonomic groups between sites. With increasing disturbance, Macroglossinae gained in average frequency (not shown), whereas Saturniidae became rarer. Reactions in Sphinginae as well as [Smerinthinae + Sphingulini] were ambiguous, but Ambulycini declined towards open, disturbed sites. With increasing altitude [Smerinthinae + Sphingulini], as well as Ambulycini, declined in frequency, whereas Macroglossinae and Sphinginae became more common. Saturniidae showed no distinctive reaction. Unexplained variation in data was large in both gradients, and a multivariate analysis did not yield statistically significant results (GLM with 5 response variables, elevation and disturbance as predictors: $R^2 < 0.22$, $F_{3, 26} < 2.5$, $p > 0.09$). Analyses of the frequency of species (not shown) revealed similar patterns as reported here for specimens, but are largely inconclusive due to their dependence upon specimen numbers.

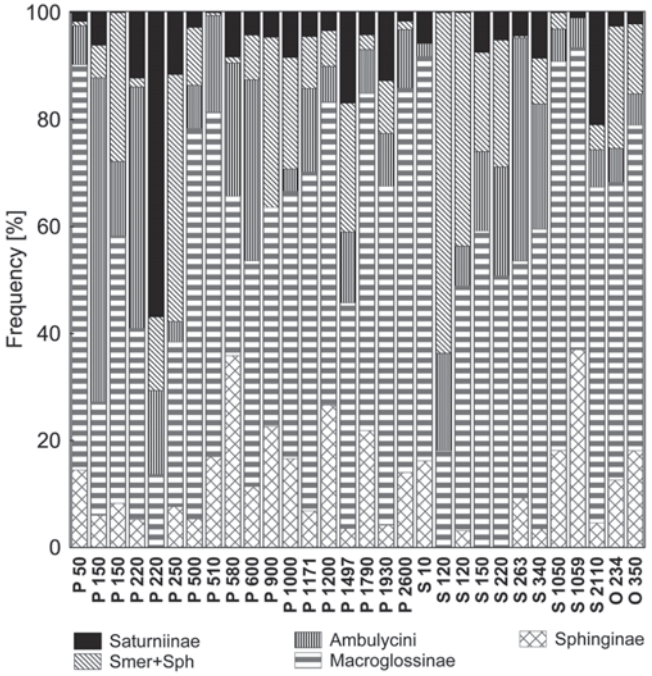

Fig. 2: Frequencies of saturniids and sphingid groups (percent of combined catch) at 30 sites of different disturbance (P = primary, S = secondary forest, O = open habitat) and altitude.

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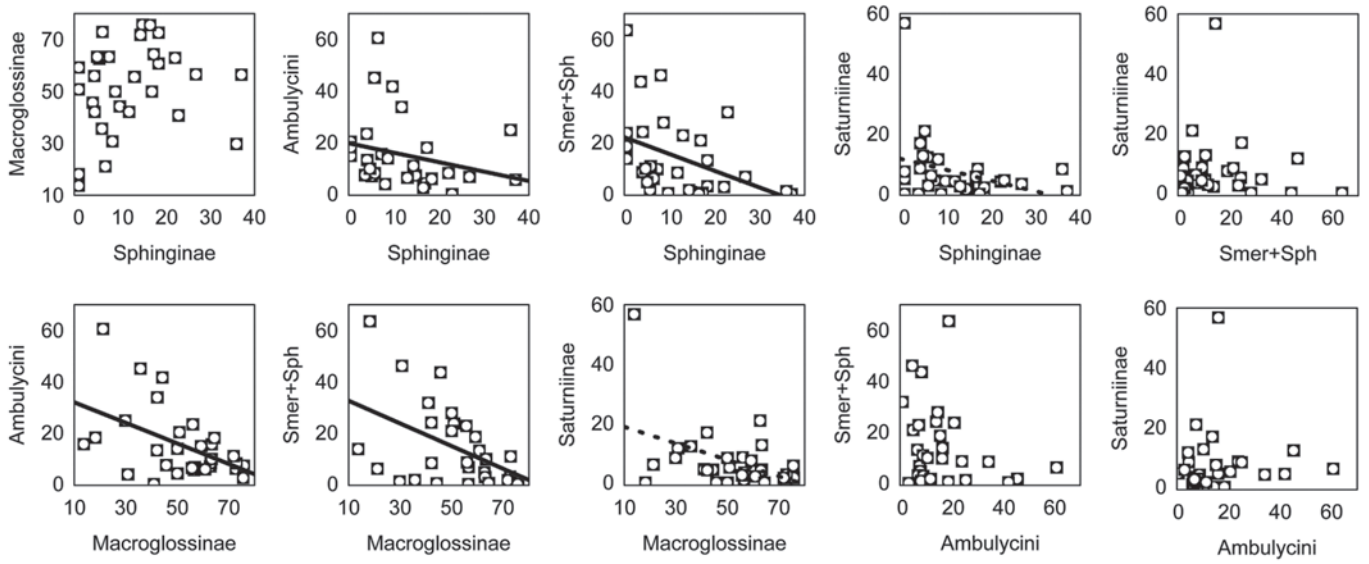

Fig. 3: Correlations of specimen frequencies of saturniids and sphingid groups (normalized by combined catch) at 30 sites in northern Borneo ("Smer+Sph": Smerinthini and Sphingulini combined). Solid regression lines indicate significant rank correlations ($p < 0.05$), dashed lines non-significant trends ($p < 0.10$). Data were normally distributed except for saturniids due to a high relative frequency at Dv1a (see Results). Excluding this site and then applying parametric regressions did not change conclusions.

To test more directly for similar ecological reaction of life-history groups, relative frequencies of taxa were correlated to each other (Fig. 3). Non-feeding sphingid groups significantly declined with increasing frequency of Macroglossinae and Sphinginae, and saturniids followed a similar trend ($p < 0.10$). However, negative correlations were also recovered between Macroglossinae and Sphinginae and adult-feeding Ambulycini. Saturniid frequencies correlated neither with non-feeding [Smerinthini + Sphingulini] nor with feeding Ambulycini (nor were the latter two groups related to each other).

Discussion

Diversity and faunal composition

No significant effects of habitat disturbance on diversity and faunal composition of saturniid assemblages were recovered. However, the exclusion of sample sites below eight individuals might have specifically excluded those sites with unfavourable conditions for saturniids. An analysis of normalized frequencies showed a (non-significant) decline in average saturniid specimen numbers with increasing disturbance. A significant change of the faunal composition of assemblages was found between site classes of different altitude, confirming topography as a major parameter of assemblage composition at local scales (e.g. Beck et al 2006a, Beck & Chey 2007 for Borneo moths).

Similarity of life-history groups

Saturniidae and non-feeding sphingid groups were expected to exhibit similar ecological reactions to habitat variation due to shared life-history characteristics. Analyses did not convincingly support this hypothesis, as no positive correlations between their frequencies were found (Fig. 3). However, corresponding with our expectations, saturniids exhibited negative correlations with some adult-feeding groups (i.e., Macroglossinae, Sphinginae), and we observed a (non-significant) pattern of saturniids being more frequent in stable, primary habitats. Most contradictory to the "life history hypothesis", however, are patterns recovered for adult-feeding Ambulycini, which largely correspond to expectations for non-feeding taxa (see also Beck et al. 2006c). Possibly a second, major factor of habitat determination, larval host plant choice, comes into play here: SE-Asian Ambulycini feed on a rather restricted set of hostplants (Beck et al. 2006b), which might be a reason for the confinement of many members of this tribe to forested habitats. At least one common species (*Ambulyx canescens*) is known to feed on Dipterocarpaceae, a dominant tree family in the canopy of lowland primary forests.

In conclusion, while there is some indication that life-history differences related to adult feeding influence specimen frequencies (cf. Tammaru & Haukioja 1996) in different habitats in SE-Asian bombycoids, the data lack unequivocal support for the prediction of similar pattern in Saturniidae and non-feeding sphingid frequencies. The ecology of the sphingid tribe Ambulycini, in particular, requires further investigation in order to understand recovered patterns. Better knowledge of phylogenetic relationships might, in the future, also help to understand patterns of ecological similarity within the "smerinthine" group of sphingids.

Results presented here must be viewed as tentative for a number of reasons. Besides taxonomic issues (see Methods and Appendix), sample sizes and species richness of saturniids are generally small in the Asian tropics, which resulted in a limited number of sites available for statistical analysis. Particularly, effects not found in the present study might yet be shown on larger data sets in the future.

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Appendix — Tentative checklist of the 27 species of Saturniidae currently known from Borneo

This checklist comprises the following information: Actual nomenclature, nomenclature according to Holloway (1987); species recorded in this study (det. JB); comments on taxonomy, identification and potential effects on analyses presented above.

Additionally to data listed, five specimens of "*Antheraea* sp." were collected at Por8, but specimens got lost. They looked similar to each other, but distinct from all taxa pictured in Holloway (1987). Particular problems for analyses presented above would arise if specimens recorded as *A. celebensis* (sensu Holloway 1987) and listed here under "*A. steinkeorum* and/or *A. broschi*" would contain several species, and if "*A.* sp." were not distinct from other taxa used in quantitative analyses (or if not all specimens of "*A.* sp." belong to the same species).

Table 1: Sampling sites: site, region, latitude [N], longitude [E], altitude, and habitat. Habitat: **F** = Forest, **F(m)** = Forest (mangrove), **M** = Mixed, **O** = Open habitat or plantation, **can** = canopy tower.

Site	Region	Latitude [N]	Longitude [E]	Altitude	Habitat
Cro1	Crocker Range	5°26′37″	116°4′47″	1170 m	M
Dv1	Danum Valley	4°57′53″	117°47′47″	220 m	F, can
Dv1a		understory below DV1			
Dv2		4°57′41″	117°51′28″	260 m	F, can
Dv3		4°57′44″	117°51′31″	220 m	F
Dv4		4°58′7″	117°50′17″	340 m	F
Lps1	Long Pasia	4°26′33″	115°43′3″	1500 m	F
Lps3		4°24′48″	115°44′7″	1060 m	O
Por1	Poring Hot Springs	6°2′33″	116°42′10″	580 m	F, can
Por2		6°2′33″	116°42′10″	500 m	F, can
Por8		6°1′33″	116°46′13″	350 m	O
Taw2	Tawau Hills	4°23′57″	117°53′22″	600 m	F
Taw3		4°22′1″	117°53′30″	230 m	O
Sep1	Sandakan	5°50′4″	117°56′6″	10 m	F
Sep2		5°49′58″	117°56′24	10 m	F
Sep4		5°50′	117°56′	0 m	F (m)
Int1	Tarakan	3°23′30″	116°40′48″	150 m	M
Int2		3°26′41″	116°46′13″	150 m	F

Format of the checklist:

Current name [*Name* according to Holloway (1987)]
Site (individuals): Specimens recorded in this study, data used for diversity analyses are listed in **bold print**.

Comment: Taxonomic comments.

Saturniidae, Saturniinae

Attacini

***Attacus atlas* Linnaeus, 1758** [*Attacus atlas*]
Cro1 (2), Dv1 (12), Dv2 (5), Dv4 (1), Lps1 (4), Por8 (7), Taw2 (2), Sep2 (1), Sep4 (2), Dv3 (1), Int1 (2)

***Archaeoattacus staudingeri* (Rothschild, 1895)** [*Archaeoattacus staudingeri*]
Por2 (1)

Comment: The second species in the genus, *edwardsii* (White, 1859), is not reliably known from Borneo despite a probably erroneous report by Fukuda (2001).

***Samia tetrica* (Rebel, 1924)** [*Samia tetrica*]
Cro1 (1), Por1 (1), Por8 (17), Int2 (1)

Comment: The genus was recently revised by Peigler & Naumann (2003).

Saturniini

***Actias maenas diana* Maassen, 1872** [*Actias maenas*]
Cro1 (12), Dv1 (5), Dv2 (2), Por1 (4)

Comment: Status of Sundaland populations (in relation to those from Indochina) somewhat unclear, but there is only one species of the group on Borneo (see Nässig 1994).

***Actias selene vandenberghi* Roepke, 1956** [*Actias selene*]
Dv1 (6)

Comment: Status of Sundaland populations not yet satisfactorily resolved (see U. & L. H. Paukstadt 1999), but there is only one species of the group on Borneo.

***Cricula trifenestrata* (Helfer, 1837) ssp.** [*Cricula trifenestrata*]
[not seen, but data from Holloway (1976) included in analyses]

Comment: Status of Borneo populations (in relation to those from Sundaland [other than Borneo] and Indochina) requires further studies. Distinction as a separate species from the following unproven, can be determined only by genitalia dissection. See Nässig (1995), Nässig et al. (1996).

***Cricula bornea* Watson, 1913** [*Cricula bornea*]
[not recorded in this study]

Comment: Status requires further studies. The somewhat enigmatic species is close to *trifenestrata*, but may represent an endemic local species of northern Borneo. Only very few reliable records known since first description. The taxon can be determined only by genitalia dissection. See Holloway (1987), Nässig (1995).

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***Cricula elaezia* Jordan, 1909 ssp.** [*Cricula elaezia*]

[not seen, but data from Holloway (1976) included in analyses]

Comment: Status of Borneo populations (in relation to those from Sundaland [other than Borneo]) requires further studies. Determination is possible by external features of specimens, but more reliable with genitalia preparations. See Nässig (1995), Nässig et al. (1996), Brechlin (2001).

***Loepa megacore* Jordan, 1911** [*Loepa megacore*]

Cro1 (6), Dv1 (8), Dv1a (2), Dv2 (1), Lps1 (2), Por1 (2), Lps3 (3) [data from Holloway 1976 included in analyses]

Comment: Status of Borneo populations (in relation to those from northern Sundaland [other than Borneo] and Indochina) still requires further research. Determination is possible by external features of specimens, but more reliable with genitalia preparations.

***Loepa sikkima javanica* Mell, 1938** [*Loepa sikkima*]

[not recorded in this study]

Comment: Status of Borneo populations (in relation to Sundaland [other than Borneo] and Indochina) still requires further research. Determination on Borneo is possible by external features, but more reliable with genital preparations.

***Lemaireia loepoides* (Butler, 1880)**
[*Lemaireia loepoides*]

Dv1 (11), Dv1a (13), Dv4 (5)

Comment: The two Sundanian species of the genus, *L. loepoides* and *L. chrysopelus,* differ manly in the colouration of the hindwing eyespot (see Nässig & Holloway 1988: fig. 1a, 1b): *L. loepoides* shows [from the centre to outside] rings in blackish brown, greyish, and brown, while *L. chrysopeplus* shows them in red, greyish, and brownish black around the hyaline core of the wing ocellus.

***Lemeireia chrysopeplus* (Toxopeus, 1940)** [Species not known to occurr on Borneo when Holloway (1987) was published.]

[not recorded in this study]

Comment: This species was originally known only from Java and Sumatra (Nässig & Holloway 1988, Nässig et al. 1996); however, material of this species reliably from southern Kalimantan is now in coll. S. Naumann, Berlin. It was dissected and found to be identical with specimens from Sumatra and Java (Naumann, pers. comm.)

For general remarks on the genus *Antheraea* Hübner, 1819 see also Nässig (1991) and U. Paukstadt et al. (2000).

***Antheraea (Antheraeopsis) youngi* Watson, 1915**
[*Antheraea assamensis*]

Cro1 (6), Dv1 (2), Dv2 (2), Por1 (1), Por8 (6), Taw2 (3)

Comment: Status of Borneo populations (in relation to those from Sundaland [other than Borneo] and Indochina) requires further research. Borneo populations do definitively not refer to *assamensis*.

***Antheraea (Antheraea) helferi borneensis* Moore, 1892**
[*Antheraea helferi*]

Cro1 (7), Dv1 (56), Dv1a (7), Dv2 (1), Por1 (4), Dv3 (1), Sep1 (1)

Comment: Status of Borneo populations (in relation to those from Sundaland [other than Borneo] and Indochina) unclear. At present, no traits are known to separate ♀♀ of *borneensis* from *diehli*. – 4 ♀♀ (2 from Dv1, 1 each from Dv1a & Por1) were tentatively associated with *borneensis* for analyses.

***Antheraea (Antheraea) diehli* Lemaire, 1979**
[*Antheraea diehli*]

Dv1 (2), Dv1a (5), Sep1 (1)

Comment: At present, no traits are known to separate ♀♀ of *borneensis* from *diehli* (see above). For polymorphic ♂♂, compare Nässig & Beck (2005).

***Antheraea (Antheraea) roylii korintjiana* Bouvier, 1928**
[*Antheraea korintjiana*]

Cro1 (1)

Comment: Status of Borneo populations (in relation to those from Sundaland [other than Borneo] and Indochina) unclear. Separation from *lampei* for some specimens difficult.

***Antheraea (Antheraea) lampei* Nässig & Holloway, 1989** [This species was described after Holloway (1987) was published.]

[not recorded in this study]

Comment: Separation from *roylii korintjiana* for some specimens difficult.

***Antheraea (Antheraea) larissa ridlyi* Moore, 1892**
[*Antheraea larissa*]

Dv1 (1), Dv4 (2), Taw2 (2), Int2 (2)

Comment: Status of Borneo populations (in relation to those from Sundaland [other than Borneo], the Philippines, and Indochina) requires further research.

***Antheraea (Antheraea) platessa* Rothschild, 1903**
[*Antheraea jana*]

Dv1 (3), Por1 (3), Por8 (1)

Comment: For the name of the species see Nässig (1992). Status of Borneo populations (in relation to those from Sundaland [other than Borneo] and Indochina) requires further research.

General note regarding "*Antheraea celebensis*": Holloway (1987) (and other earlier authors publishing about SE Asian regional faunas, e.g. Lampe 1984, 1985, Nässig et al. 1996) combined a complex of 4, possibly more, species under the name "*A. celebensis* Watson, 1915" (or under other, equally misinterpreted names). The identity and relationships within the group are presently not yet satisfactorily resolved; we follow here Naumann (2001),

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who was the first recent author attempting to solve these problems.

***Antheraea (Antheraea) steinkeorum* U. & L. H. Paukstadt & Brosch, 1999**

and/or

***Antheraea (Antheraea) broschi* Naumann, 2001**

[both included in Holloway 1987 under *Antheraea "celebensis"*]

Cro1 (2), Dv1 (9), Dv1a (2), Por8 (1), Taw3 (1) [data from Holloway 1976 included in analyses]

Comment: Status and identity of Borneo populations still unsufficiently assessed, but they are definitively not *celebensis*. Some of the species are probably still species-complexes, see Naumann (2001). Holloway (1987: plate 11, no. 3) had also included an illustration of *A. moultoni* under his so-called *A.* "*celebensis*".

***Antheraea (Antheraea) zwicki* Nässig & Treadaway, 1998**

and/or

***Antheraea (Antheraea) gschwandneri* Niepelt, 1918**

[both also included in Holloway 1987 under *Antheraea "celebensis"*]

(These two species are usually very rare and were most likely not recorded in error under *A.* "*celebensis*" in this study.)

Comment: Status and identity of Borneo populations (in relation to those from Sundaland [other than Borneo] and [for *gschwandneri* only] Indochina) still unsufficiently assessed (synonymy of *myanmarensis* U. & L. H. Paukstadt & Brosch, 1998 with *gschwandneri* already indicated by Naumann 2001), but they are definitively not *celebensis*. *A. zwicki* was described from Palawan misidentified as a subspecies of *gschwandneri* (see Nässig & Treadaway 1998), but it is a separate species and also found on Borneo (Naumann pers. comm.).

***Antheraea (Antheraea) moultoni* Watson, 1927**

[*Antheraea moultoni*]

Cro1 (1), Dv1 (1), Lps1 (3)

Comment: Considered a species of the lowlands and mangroves, but see records from Cro1 and Lps1. Probably endemic to Borneo.

***Antheraea (Antheraea) alleni* Holloway, 1987**

[*Antheraea alleni*]

Dv3 (1)

Comment: Considered a montane species (but see record Dv3 and Holloway 1987), probably endemic to Borneo.

***Antheraea (Antheraea) brunei* Allen & Holloway, 1986** [*Antheraea brunei*]

[not recorded in this study]

Comment: Apparently a species of the mangroves, probably endemic to Borneo and a few smaller islands nearby.

***Antheraea (Antheraea) rosieri* (Toxopeus, 1940)**

[*Antheraea rosieri*]

Cro1 (7), Dv1 (9), Dv2 (1), Dv4 (1), Lps1 (5), Taw2 (1)

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